Electrostatic Enhanced Compact Aerosol Concentrator Development

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Electrostatic Collection Technology

Acknowledgements

- The Electrostatic Enhanced Compact Aerosol Concentrator Development Program is part of the Technology Transfer Program being funded by DTRA / SBCCOM, under the technical direction of the Edgewood Chemical Biological Center

- Technical Point of contact Dr. J. Bottiger, Dr. E Steubing

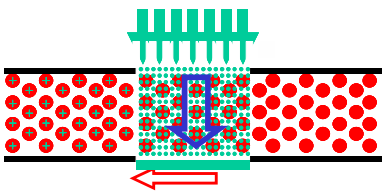
Electrostatic Collection Technology

…versatile technology capable of interfacing to many detection modalities…

AEROSOL

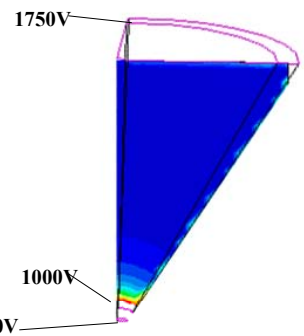
Charging

- Corona-charging
- Optimum Charge Saturation



Sample Deposition

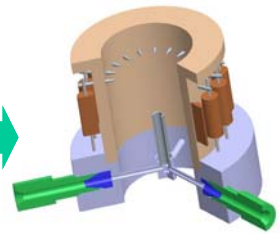
- Electrostatic Focusing & Deposition



Liquid

Self-cleaning Hydrophobic Membrane

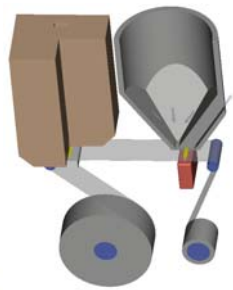
Wetted Column



Surface

Electrostatic Sorting for Particle Enrichment

Gentle Low Velocity Deposition on Tape



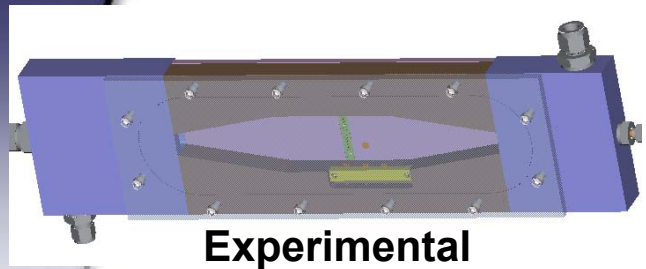
Assay or Antibody Detection System requiring small volume samples (< ml)

Spectra-graphic Detection System

Electrostatic Enhanced Compact Aerosol Concentrator Development

…Roadmap…

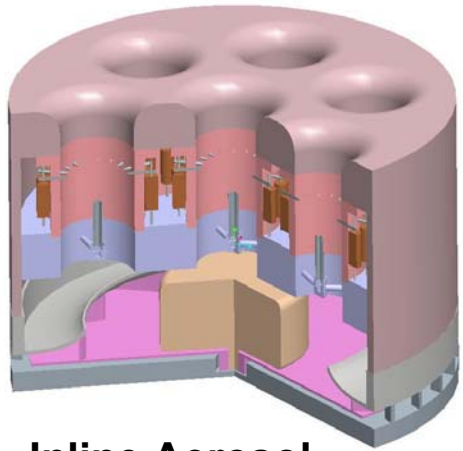
FY 03



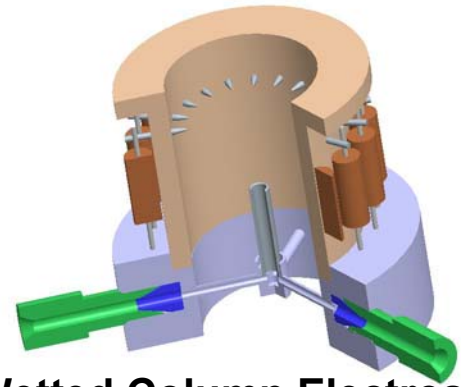
Experimental Electrostatic Capture Module

Hydrophobic Membrane

FY 04

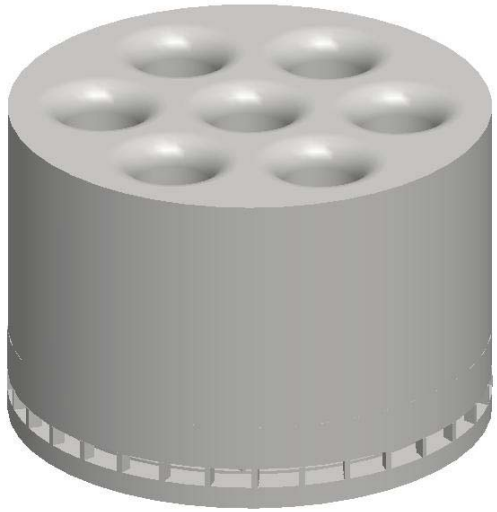


Inline Aerosol Concentrator



Wetted Column Electrostatic Capture Module

FY 05



Compact Electrostatic Aerosol Concentrator Prototype

Electrostatic Enhanced Compact Aerosol Concentrator Development

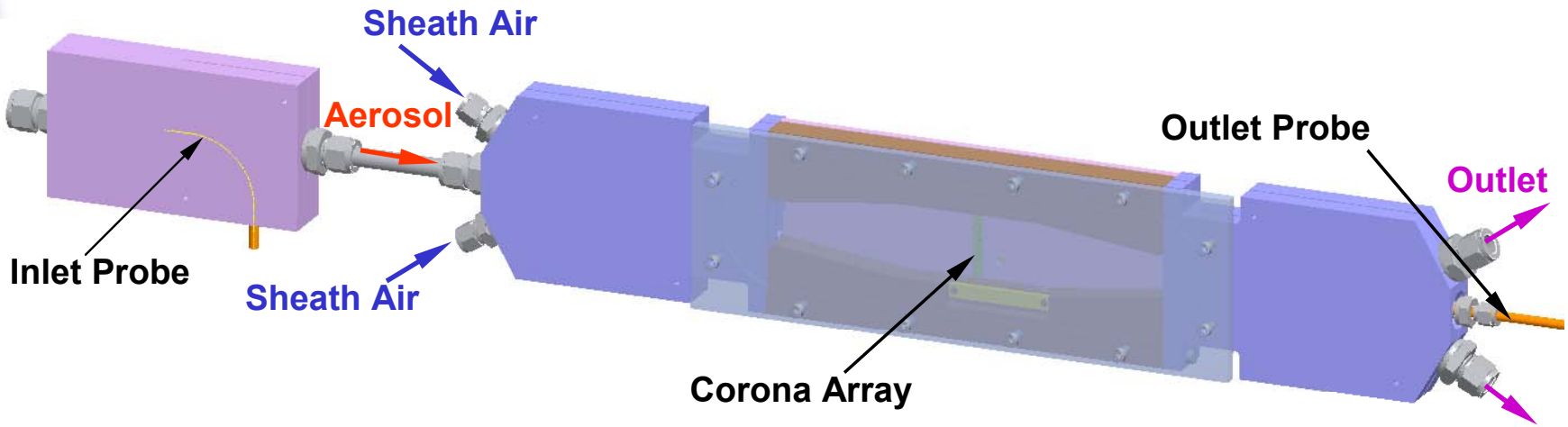
…Description of Current Effort…

- **Moderately concentrated aerosol drawn through experimental capture duct**
  - **simulates the output of a cyclone concentrator**
  - **monodispersed aerosol consisting of fluorescent beads**
  - **sheath air employed to confine aerosol stream**
- **Electrostatically charged by corona array**
- **Particles electrostatically focused directly into small liquid volume**
  - **beads deposited on solid surface in initial experiments**
- **Component configuration modified to optimize collection efficiency**
- **Performance determined by fluorescent imaging techniques**

Electrostatic Enhanced Compact Aerosol Concentrator Development

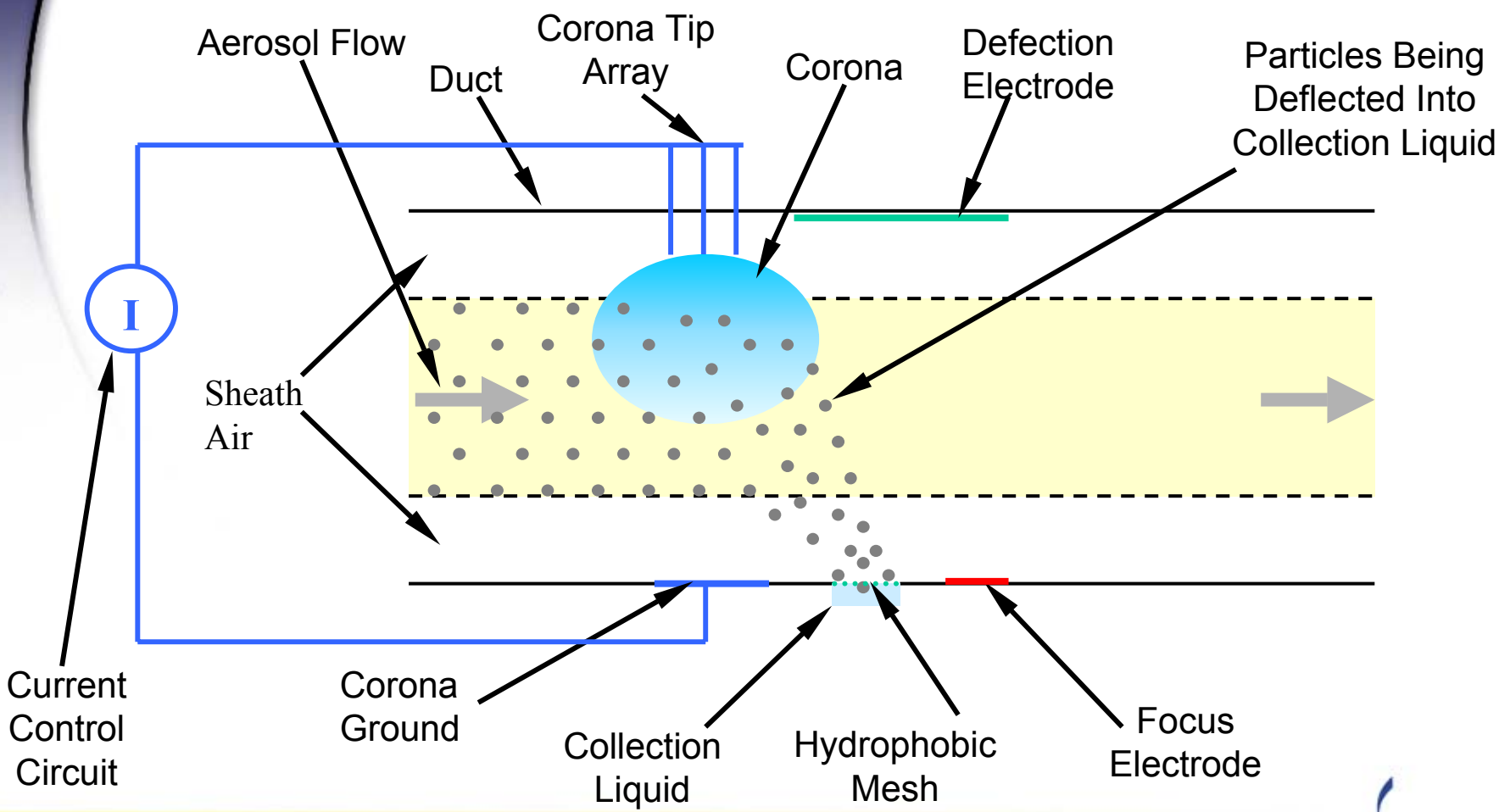
…experimental set-up for optimizing electrostatic capture configuration…

Orthogonal Collection Approach



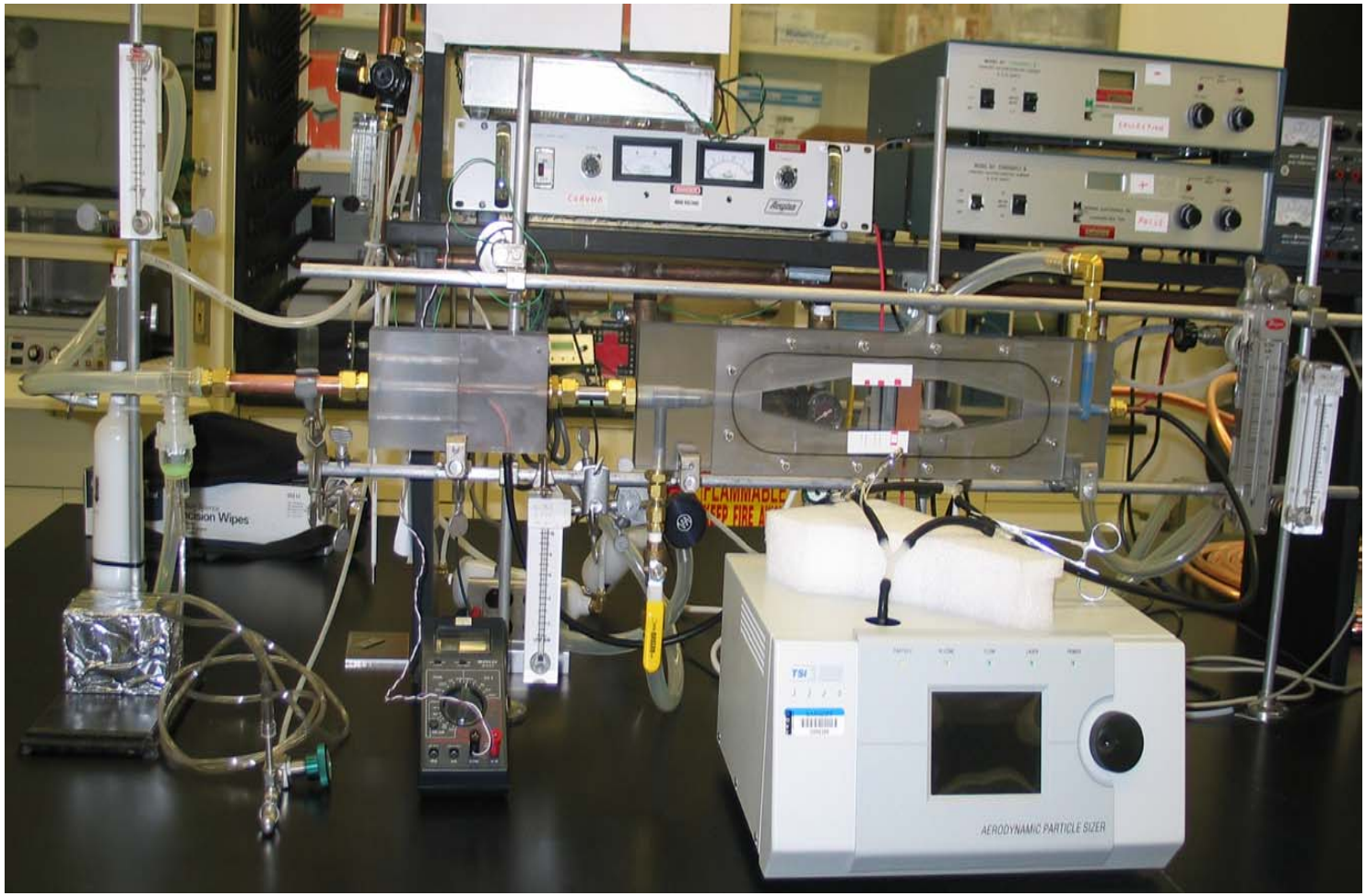
Electrostatic Focusing of Particles Into a Liquid Using Corona Charging & Transport

Operation Schematic for Orthogonal Collection Approach



Electrostatic Enhanced Compact Aerosol Concentrator Development

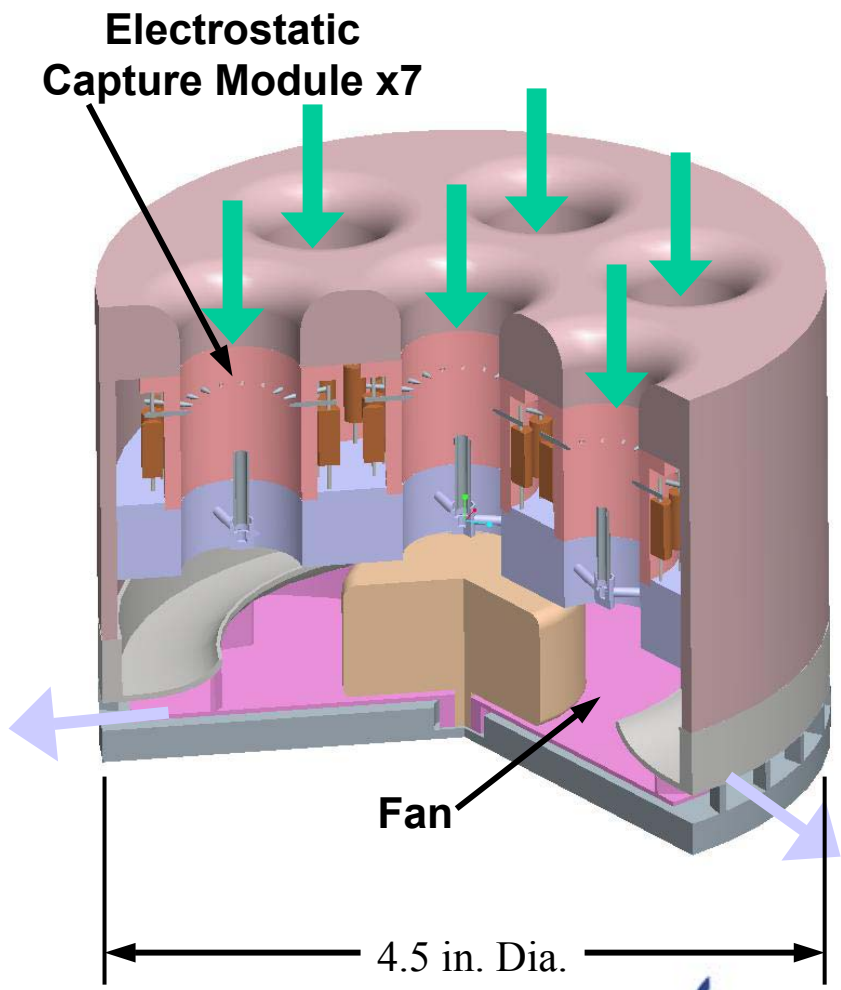
…experimental set-up for optimizing electrostatic capture configuration…



Compact Electrostatic Aerosol Concentrator

...compact, low power, high flow rate...

- **Direct aerosol concentration without energy consumptive inertial separation process upstream**
  - **Pressure drop orders of magnitude lower than inertial separation collector**
  - **7 unit array samples 210 LPM with 1 watt fan**
- **Particles charged by radial array of corona tips**
- **Particles deposited onto small liquid wetted column located on the axis of the aerosol duct**



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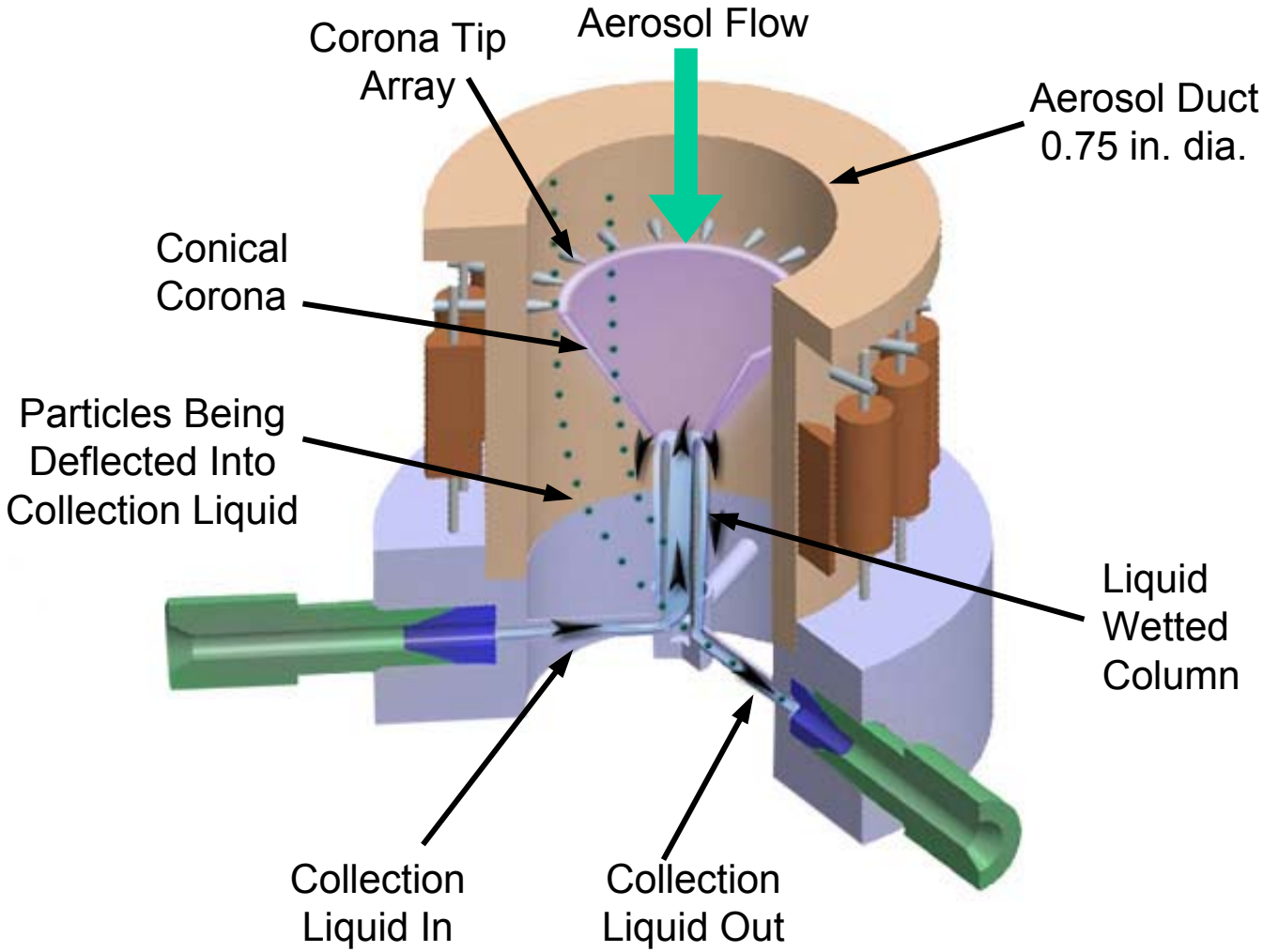
Electrostatic Focusing of Particles Onto Liquid Wetted Column Concept



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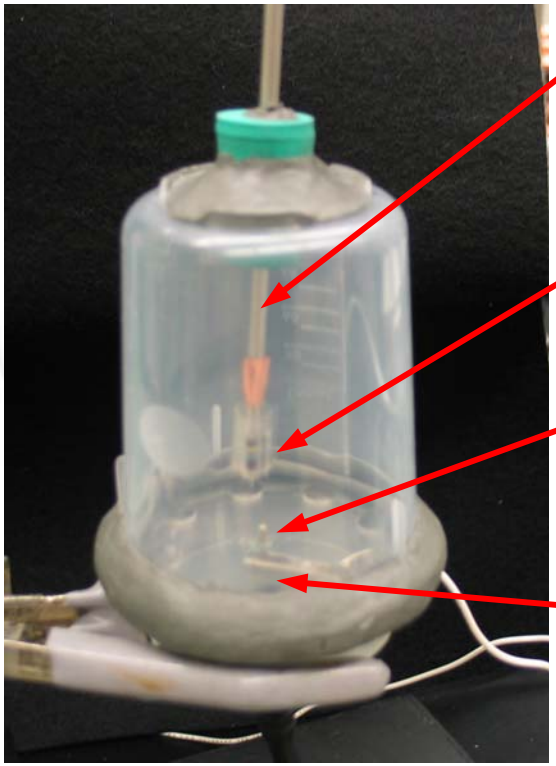
Electrostatic Focusing of Particles Onto Column Experiments

Test Setup

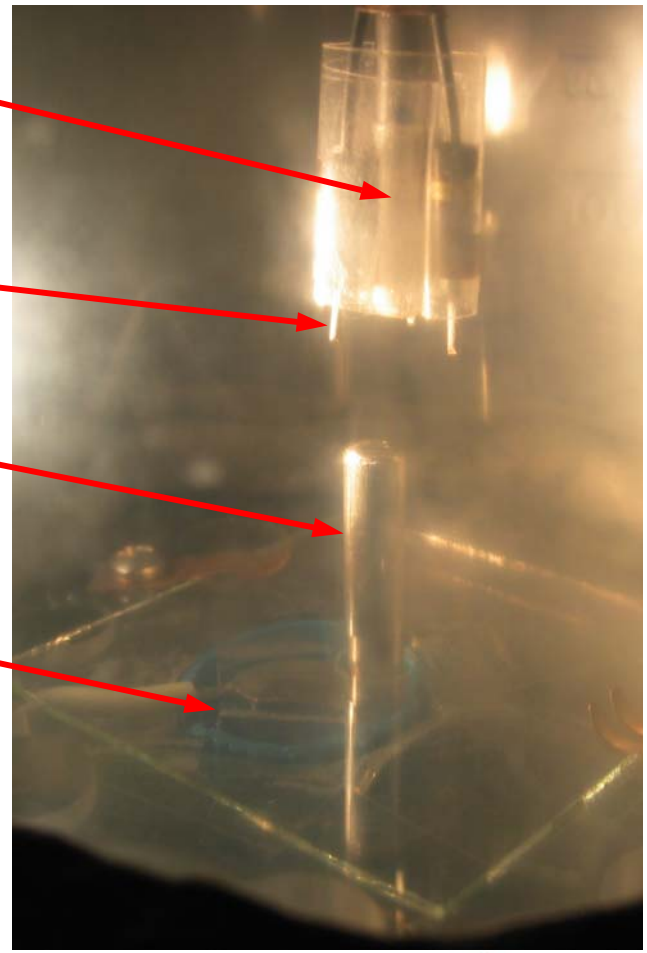


2.5 mm diameter nozzle

Corona Array

1.5 mm dia. dry column

ITO coated glass focus electrode

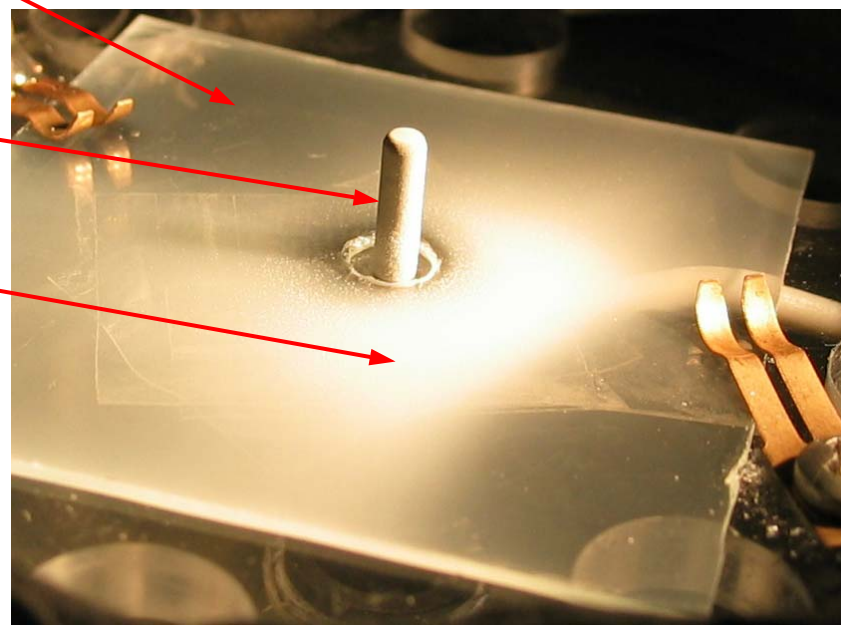


Electrostatic Focusing of Particles Onto a Column Experiments

Electrostatic deposition of smoke onto a 1.5 mm diameter dry column @ 1 liter per minute aerosol flow rate through 2.5 mm diameter nozzle

ITO coated glass focus electrode

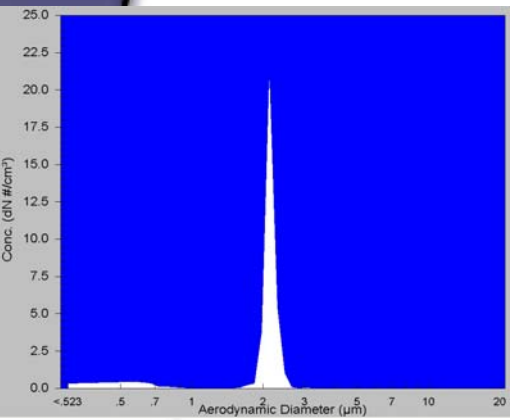
1.5 mm diameter dry column ground electrode



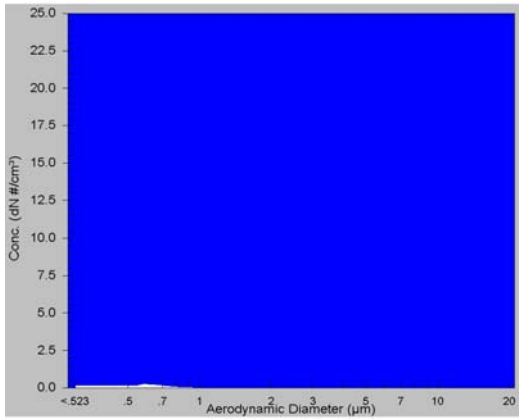
- Excess deposition beyond column occurs when deposited particles form insulating layer preventing newly arriving particles from discharging to the column ground
- The particles than repel each other causing them to be deposited on the surrounding surface.
- This will not occur in the actual implementation of the technology where the aerosol density is orders of magnitude lower than that of the smoke used to visualize the aerodynamic characteristics of the collector.

Electrostatic Focusing of Particles Onto Column Experiments – AEROSOL DATA

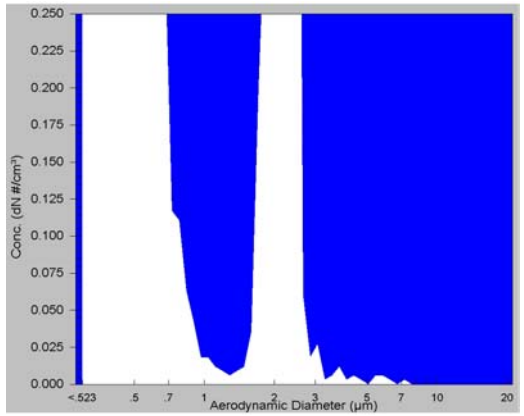
Electrostatic deposition of 2.3 μ beads onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate



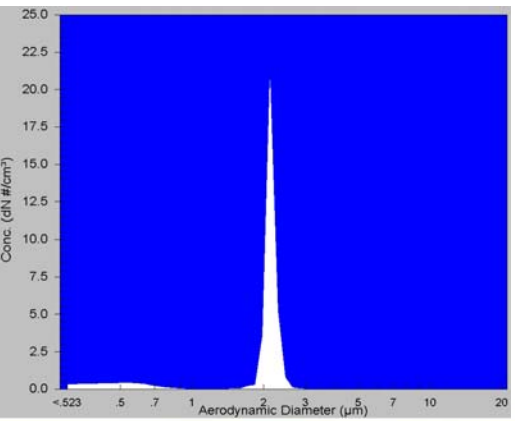
Electrostatics Off

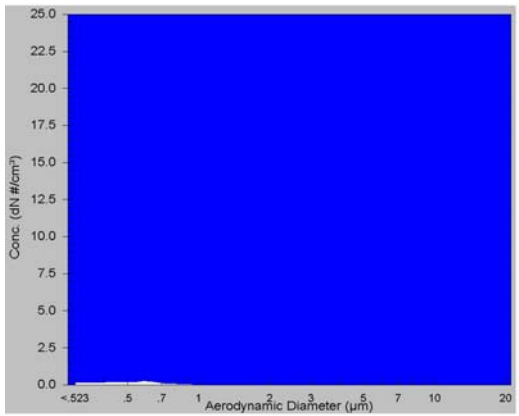


Electrostatics On

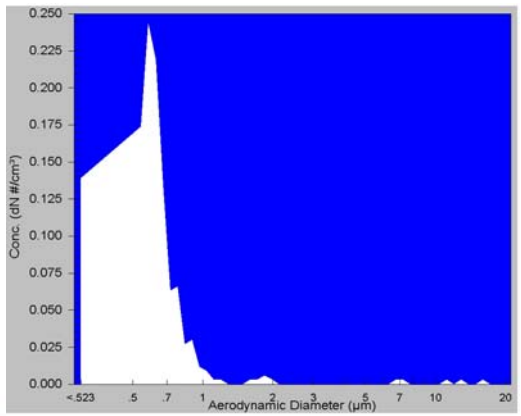


Electrostatics Off 10X





Electrostatics On 10X

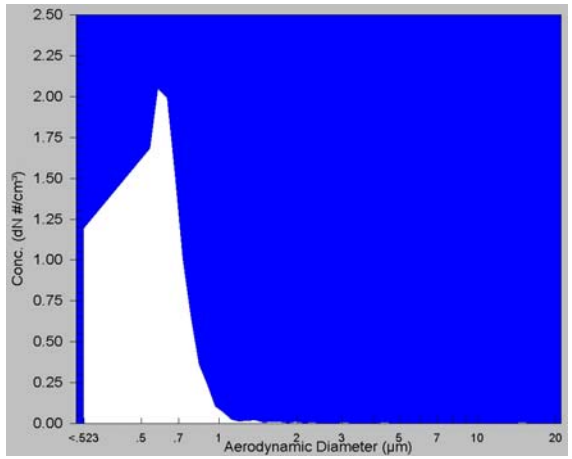


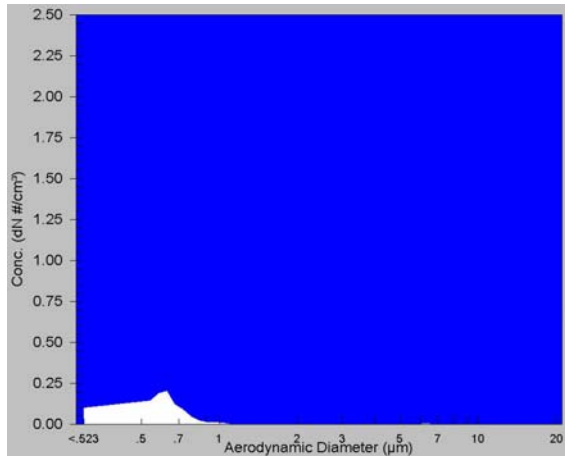
> 99% of 2.3 μ Particles Removed From Aerosol by Electrostatic Collection

Electrostatic Focusing of Particles Onto Column Experiments – AEROSOL DATA

Electrostatic deposition of room air onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate

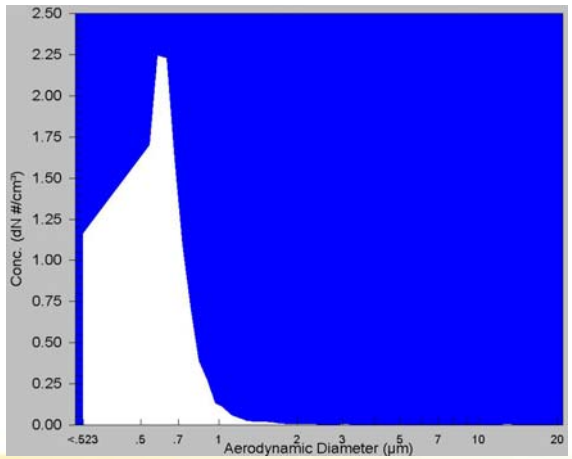
> 90% of 0.5 m Particles removed from Aerosol by Electrostatic collection

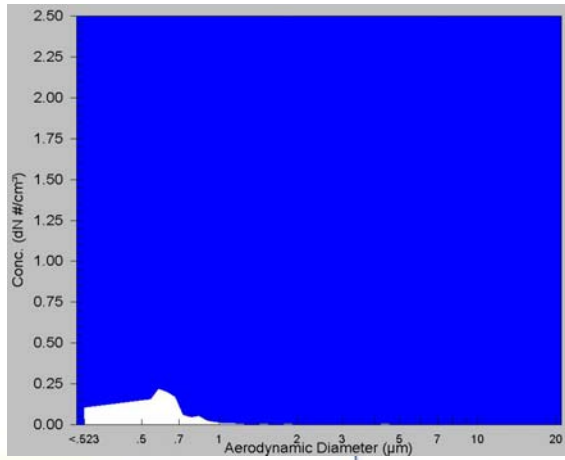




Electrostatics Off

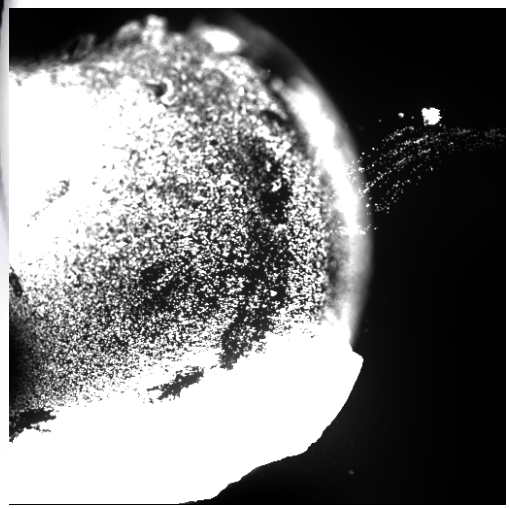
Electrostatics On



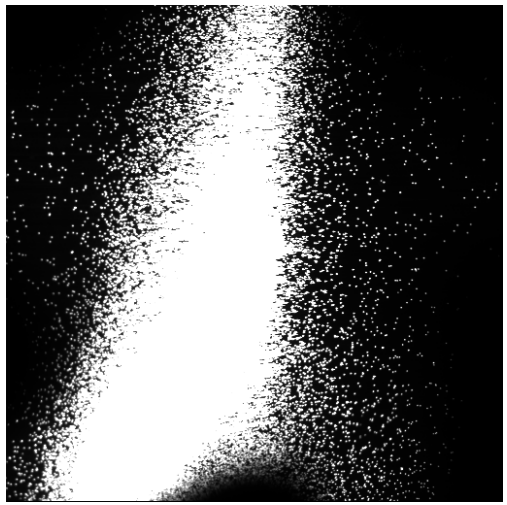


Electrostatic Focusing of Particles Onto Column Experiments – DEPOSITION DATA

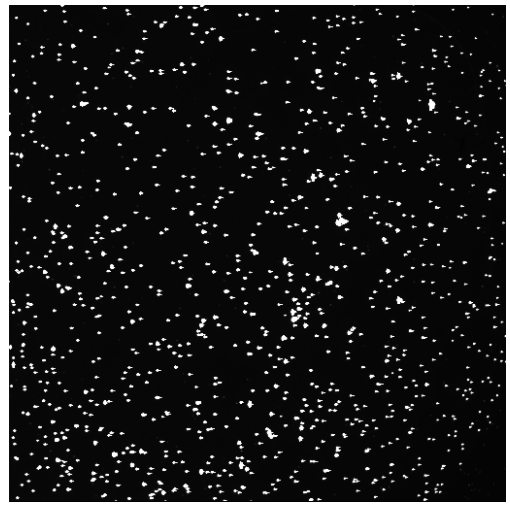
Electrostatic deposition of 2.3 μ fluorescent beads onto a 2 mm diameter dry column with 3 mm diameter nozzle @ 1 liter per minute aerosol flow rate



Top of Column



Side of Column



Focus Electrode

Deposition predominantly on column collection surfaces

Small amount on the focusing electrode surface

Half this density of particles observed on focusing electrode surface with the electrostatics turned off.

BACKGROUND

Corona Charging Technology

…developed on independent program involving electrostatic deposition of pharmaceuticals …

- **Corona charging advancements**
  - Developed new corona charging technique superior to currently available technology
  - High efficiency (demonstrated >99%) uni-polar charging
  - Current controlled corona eliminates ion density variation due to tip erosion
  - Array of Corona tips generates uniform corona
- **Corona wind management**
  - "wind" blows particles toward collection port
  - controlled by tip array

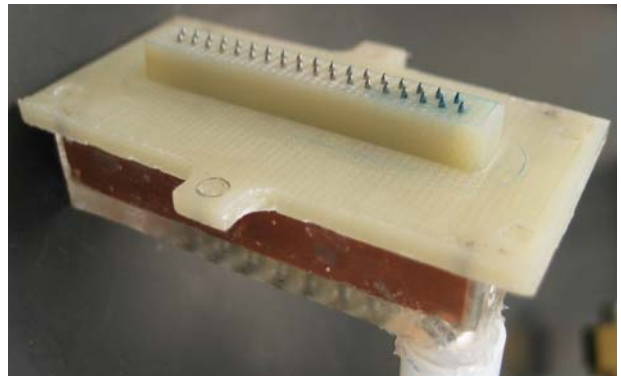
Charging

- Corona-charging
- Optimum Charge Saturation

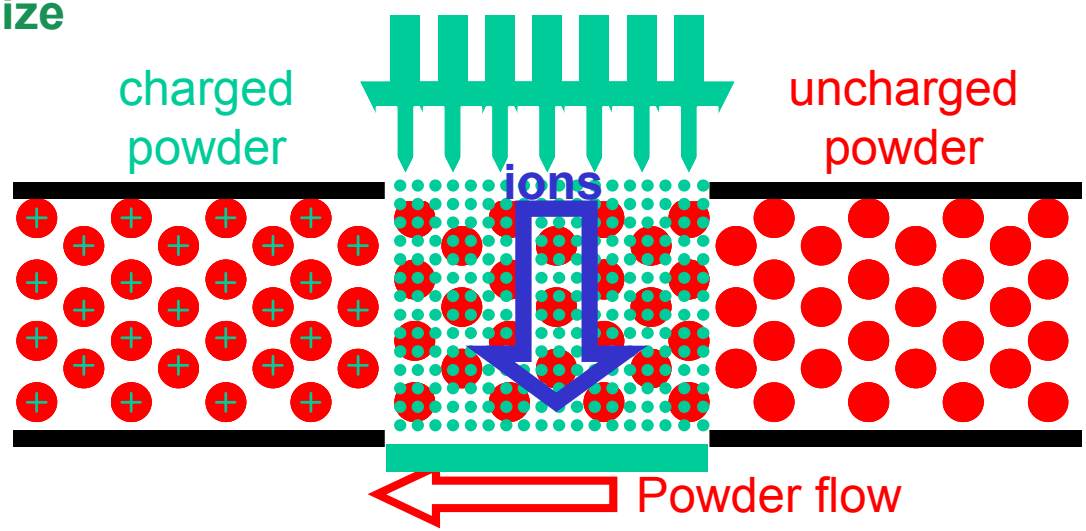
BACKGROUND

Corona Charging Technology

- **Advantages of corona charging**
  - Predictable particle charging
  - Charging obeys Pauthenier equation
  - Field charger
  - Uses maximum E-Field for capture
  - Designed for theoretical efficiency for respirable particle size



Corona Tip Array



Unipolar Charging

Charging

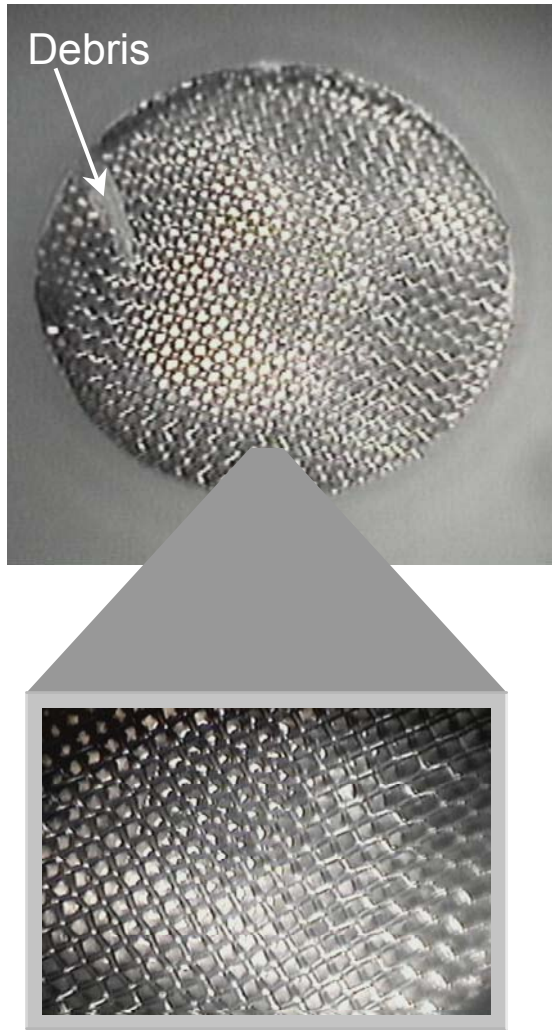
- Corona-charging
- Optimum Charge Saturation

BACKGROUND

Self Cleaning Liquid-Air Interface

...withstand differential pressure with efficient particle transport...

- **Teflon treated nylon mesh retains liquid in collection channel**
  - Debris tolerant
  - 40% open area
  - Low cost - standard Teflon fabric treatment
  - thermal imbedment assembly
- **Self Cleaning**
  - over pressurize channel to purge liquid past mesh to rinse contaminants off surface
  - liquid seal re-established when pressure is reduced



Results in clog-free, low-maintenance continuous operation

Liquid
- Self-cleaning Hydrophobic Membrane

Electrostatic Surface Deposition
…Benefits …

- **Superior to impaction methods**
  - **Better control of deposition parameters**
    - **Smaller size sample**
    - **Potential to deposit mono layer**
  - **Less likely to damage pathogen**
    - **Gentle Low Velocity Deposition**
  - **Lower pressure drop**
    - **Lower power**
    - **Quieter aerosol collection fan**
- **Tape transport from collector to detector**
  - **Rapid, automated, precise location**
  - **Tape configuration:**
    - **Disposable - reel to reel**
    - **Reusable - loop**
    - **Materials - polymer, ceramic, metal**

Surface
- Low Velocity Deposition

Electrostatic Sorting

…sample enrichment by electrostatic deflection of selected particles…

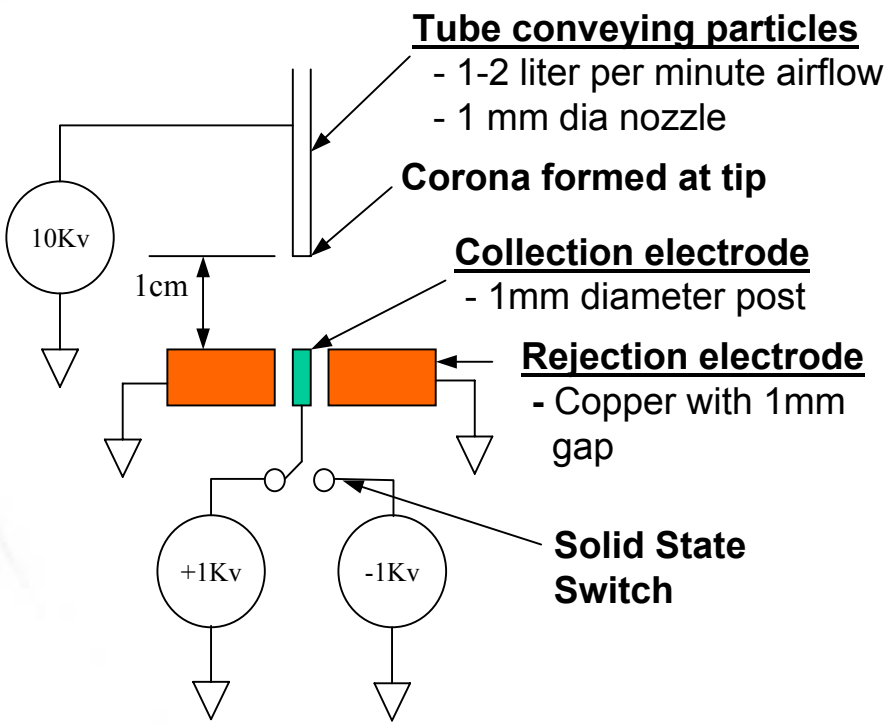
- **Description of operation**
  - Stream of particles electrostatically charged by corona created at the exit of nozzle
  - Particles interrogated by UV laser
  - resulting laser induced fluorescence used to determine particles of biological origin
  - Selected particles focused onto small diameter target
  - rejected particles deflected to annular surface surrounding target
- **Features**
  - High S/N ~ 50,000:1
  - High switching speeds > 10Khz
  - High efficiency (>99% @ 2um)

Surface

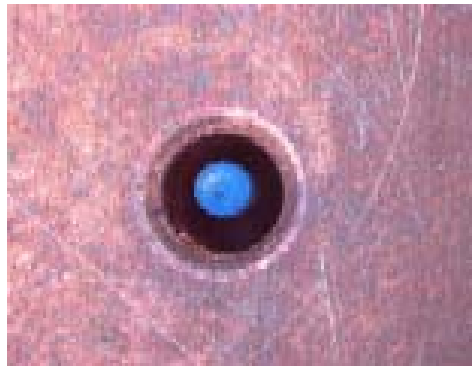
Sorting

Electrostatic Sorting

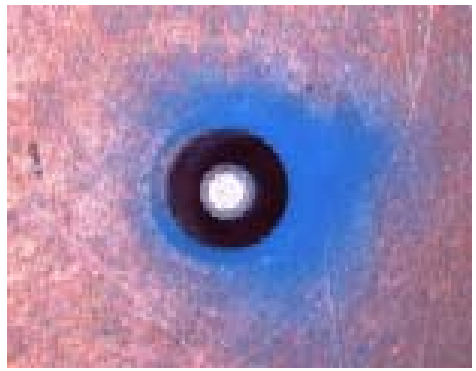
…feasibility experiment…



Experimental electrostatic sorting mechanism



Experimental result showing deposition of HP cyan toner (3um-9um) particles onto collection electrode



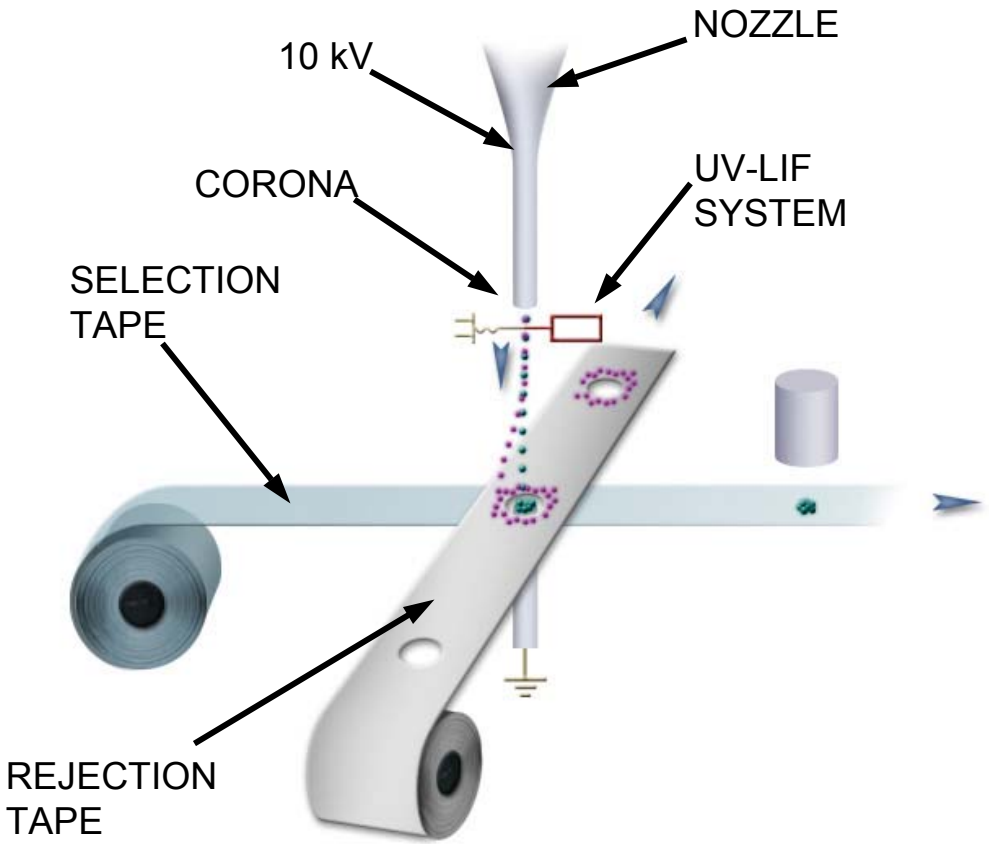
Experimental result showing deposition of HP cyan toner (3um-9um) particles onto rejection electrode

Surface

Sorting

Electrostatic Sorting

…deposition onto tape concept …



Surface

Sorting

SUMMARY

Benefits of Electrostatic Collection

- **Affords plug and play detector integration for standardized air sampling module**
  - Deposition into liquid for assay and antibody based detection
  - Solid surface deposition for spectrographic detection
  - Electrostatically focused aerosol stream for advanced particle sorting techniques
- **Electrostatically focus particles into μl liquid volumes**
  - Interfaces to advanced detection technologies
  - Clog free hydrophobic membrane
  - Capable of low temperature operation
- **Electrostatic surface deposition superior to impaction methods**
  - Better control of deposition parameters
  - Less likely to damage pathogen
  - Lower pressure drop reduces fan power & noise